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IN RE APPLICATION OF	:
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FOR: APPARATUS AND METHOD FOR PREPARING AND SUPPLYING SLURRY FOR CMP MACHINE	:

SUBMISSION OF CERTIFICATION AND
CERTIFIED ENGLISH TRANSLATION OF JP 2002-263738

COMMISSIONER FOR PATENTS
ALEXANDRIA, VIRGINIA 22313

SIR:

Further to our response filed July 19, 2005, enclosed herewith for the Examiner's review is the Certification and certified English translation of the JP 2002-263738 priority document, which was requested in the Official Action dated May 2, 2005, which stated that "should applicant desire to obtain the benefit of foreign priority under 35 U.S.C. 119(a)-(d) prior to declaration of an interference, a translation of the foreign application should be submitted under 37 CFR 1.55 in reply to this action."

Respectfully Submitted,

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DECLARATION

I, YOSHIDA Katsuhiro of 238, Nishikananoi, Showa-machi, Kitakatsushika-gun, Saitama-ken, Japan do hereby declare that I am well acquainted with the Japanese language and English language and the attached English translation of an officially certified copy of Japanese Patent Application No.2002-263738 is a true and correct translation to the best of my knowledge and belief from the Japanese language into English language.

Declared on this 20th day of July , 2005, in Tokyo, Japan

K. Yoshida

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JAPAN PATENT OFFICE

This is to certify that the annexed is a true copy of the following application as filed with this Office

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Applicant: m · FSI LTD.

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IMAI Yasuo (sealed)
Commissioner,
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【Title of the Invention】 Apparatus for Mixing and Supplying Slurry and Method for Mixing and Supplying Slurry

【Number of Claims】 7

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[Name of Document] Specification

[Title of Invention] Apparatus for Mixing and Supplying Slurry and Method for Mixing and Supplying Slurry

[Claims]

[Claim 1] An apparatus for mixing and supplying a slurry to a chemical mechanical polishing machine, said slurry containing liquid components, which comprise at least a dispersion of fine abrasive particles and a solution of an additive, at a predetermined mixing ratio, comprising: draw ports for separately drawing therethrough said liquid components, said draw ports corresponding in number to said liquid components; a discharge port for supplying said slurry to said chemical mechanical polishing machine; feed pumps arranged on feed lines for said liquid components, respectively, said feed lines extending from said individual draw ports to said discharge port, such that said feed pumps can draw the corresponding liquid components in specific amounts to give said mixing ratio and can deliver the thus-drawn liquid components toward said discharge port, respectively; dampers and pressurization valves arranged in combinations on the respective feed lines on delivery sides of said feed pumps; flow-meters arranged on said respective feed lines on downstream sides of the corresponding combinations of said dampers and pressurization valves for measuring delivery rates from the

corresponding feed pumps; and a programmable logic controller for controlling delivery rates of the individual feed pumps by using measurement values from said flow-meters.

[Claim 2] An apparatus according to claim 1, further comprising at least one isolator arranged between one of said draw ports and its corresponding feed pump.

[Claim 3] An apparatus according to claim 1, wherein said programmable logic controller performs PID control by using deviations of measurement values of said respective flow-meters from predetermined flow rates preset for delivering said liquid components in specific amounts by said feed pumps, respectively, and also control to follow up changes in said predetermined flow rates.

[Claim 4] An apparatus according to any one of claims 1 - 3, further comprising a feed line for feeding deionized water to said feed line for said dispersion of fine abrasive particles and a means for cleaning and flushing with the deionized water said feed line for said dispersion of fine abrasive particles.

[Claim 5] An apparatus according to any one of claims 1 - 4, further comprising a mixer arranged on said feed lines at a position between said individual flow-meters and said discharge port for performing mixing of said individual liquid components.

[Claim 6] A method for mixing and supplying, to plural chemical mechanical polishing machines, slurries as required by said chemical mechanical polishing machines, which comprises

connecting slurry mixing and supplying apparatuses as defined in any one of claims 1 - 5 to said chemical mechanical polishing machines, respectively, such that said liquid components, which comprise at least said dispersion of fine abrasive particles and said solution of said additive, can be in parallel supplied to said individual chemical mechanical polishing machines via the corresponding slurry mixing and supplying apparatuses.

[Claim 7]. A method according to claim 6, further comprising: inputting from said individual chemical mechanical polishing machines to said programmable logic controller information on predetermined amounts of said individual liquid components required by said chemical mechanical polishing machines, respectively; monitoring for changes in said predetermined amounts; and performing control of delivery rates from said respective feed pumps by using deviations of measurement values of said flow-meters from said predetermined amounts.

[Detailed Explanation of Invention]

[0001]

[Technical Field of the Invention]

This invention relates to an apparatus for mixing at least a dispersion of fine abrasive particles and a solution of one or more additives at a predetermined mixing ratio to prepare a slurry and supplying the slurry to a chemical mechanical

polishing machine which is adapted to polish and planarize with high accuracy the surfaces of substrates such as wafers, and also to a slurry mixing and supplying method making use of the apparatus.

[0002]

[Prior Arts]

Keeping in step with a move toward LSIs of higher integration and higher performance in recent years, chemical mechanical polishing (CMP) is attracting attention as a working method for planarizing with high accuracy the surfaces of substrates such as wafers. Employed in polishing machine is a slurry prepared by mixing a dispersion of fine abrasive particles (hereinafter called "concentrated slurry") with a solution of additives (hereinafter called "additives solution"). The concentrated slurry contains a polishing abrasive, which is composed of fine particles of silica, alumina, zirconia, manganese dioxide or ceria (cerium oxide), in a form dispersed in an aqueous alkaline solution of potassium hydroxide, ammonia or the like or in a water containing a surfactant. The additives solution, on the other hand, contains various additives selected depending on the work to be polished, such as a surfactant and an oxidizing agent for promoting chemical action such as hydrogen peroxide or ferric nitrate. Therefore, the slurry is a solution with the polishing abrasive and additives mixed and dispersed therein, and is used in actual polishing. Excellent polishing is achieved

by a combination of chemical action, which occurs between the additives solution in the slurry and each substrate, and mechanical action between the polishing abrasive in the slurry and the substrate.

[0003]

When polishing, for example, a silicon dioxide film (oxide film) of an interlayer insulation material on a semiconductor silicon substrate by a polishing machine, a slurry is used with a concentrated slurry of silica particles diluted in an aqueous alkaline solution, for example, an aqueous solution of potassium hydroxide added to improve the dispersibility of the silica particles and also to form a particle agglomeration state optimal for the polishing. The slurry is fed onto the semiconductor silicon substrate mounted on the polishing machine, and the oxide film is removed by mechanical polishing between the silica particles in the slurry and a polishing pad of the polishing machine.

[0004] When polishing a tungsten metal film formed as an interconnecting material, an alumina slurry is used with a concentrated slurry of alumina particles diluted in hydrogen peroxide solution added as an oxidizing agent. By supplying the slurry onto the semiconductor silicon substrate mounted on a polishing machine, the surface of the tungsten film and hydrogen peroxide are caused to undergo a chemical reaction to form a tungsten oxide film which permits easy polishing. The film

formed by the reaction is polished by mechanical polishing between the alumina particles as a polishing abrasive and a polishing pad of the polishing machine such that the film is removed at unnecessary areas other than interconnecting lines.

[0005] As an apparatus and method for supplying a slurry to such a chemical mechanical polishing machine as described above, it has been a common practice to mix a concentrated slurry, which contains a polishing abrasive chosen as desired, with an additives solution containing a surfactant, an oxidizing agent and the like and further, with diluting water, which may be used as needed, at a predetermined ratio in advance, and subsequent to temporary accumulation of the mixture in a storage tank, to supply the slurry to a polishing machine. These apparatus and method are, however, accompanied by a problem in that a slurry containing its components at a desired mixing ratio cannot be supplied adequately in a good form suitable for the polishing due to a deterioration in the polishing characteristics of the slurry and a reduction in the dispersibility of fine polishing particles in the slurry with time while being held in the storage tank after the mixing or due to low flexibility and applicability upon changing the mixing ratio of components which make up the slurry. With a view to coping with this problem, a slurry supplying apparatus has been proposed(please refer to patent reference 1). According to this slurry supplying apparatus, an aqueous solution of abrasive particles (concentrated slurry)

and an additives solution are mixed together by a mixer shortly before they are injected against a polishing pad of a polishing machine, so that the plural solutions are supplied as a slurry.

[0006] According to an investigation by the present inventors, however, the slurry supplying apparatus disclosed in said patent documents has been found to involve problems as will be described next. The mixing accuracy of slurry components depends solely upon flow-meters and constant flow rate valves the openings of which are feedback controlled by the flow-meters, respectively. In flow-meter, however, there is a substantial error especially in a low flow rate range when its accuracy is considered. In constant flow rate valve, on the other hand, there is a concern about its clogging with a concentrated slurry. With such a construction as described above, a slurry may not be adequately supplied at a particular mixing ratio of its liquid components suitable for desired polishing in some instances. Furthermore, in the conventional apparatus described above, plural liquid components are fed by their pumps to the apparatus. According to an investigation by the present inventors, the above-described system was found to have a difficulty in maintaining the mixing accuracy of liquid components in a slurry at high accuracy level because pulsations (pressure fluctuations) of the pumps employed there deleteriously affect the maintenance of constant flow rates at the constant flow rate valves. While a mixed solution remains unused, fine particles

in the slurry may settle or agglomerated so that internal piping may be clogged. The above-described conventional apparatus, however, does not permit removal of such settled or agglomerated, fine particles because it is not equipped with any cleaning and flushing machine for an area where mixing is performed. Especially in an initial stage after resuming supplying the slurry, a problem is considered to still remain unsolved in maintaining the accuracy of the mixing ratio.

[0007]

[Patent Reference 1] JP 2000-202774 A

[0008]

[Problems Sought for Solution by the Invention]

An object of the present invention is, therefore, to provide an apparatus for mixing and supplying a slurry to a chemical mechanical polishing machine, which can supply the slurry at an optional flow rate suited for desired working or machining to the polishing machine, with its liquid components mixed together at a high-accuracy mixing ratio, in a good state free of any substantial deterioration, and in an appropriate and simpler manner.

An additional object of the present invention is to provide a method for mixing and supplying slurries to plural chemical mechanical polishing machines, respectively, which can supply the slurries at optional flow rates suited for desired working or machining operations to the chemical mechanical polishing

machines, with their liquid components mixed together at high-accuracy mixing ratios, in good states free of any substantial deterioration, and in an appropriate and simpler manner.

A further object of the present invention is to provide an apparatus for mixing and supplying a slurry, which can maintain the mixing ratio of its liquid components with high accuracy even in an initial stage after the supply of the slurry is resumed subsequent to a temporary halt.

[0009]

[Means for Solution of the Problems]

The above-described objects can be achieved by the present invention which will be described hereinafter. Described specifically, the present invention, in one aspect thereof, provides an apparatus for mixing and supplying a slurry to a chemical mechanical polishing machine. The slurry contains liquid components, which comprise at least a dispersion of fine abrasive particles and a solution of an additive, at a predetermined mixing ratio. The apparatus includes draw ports for separately drawing therethrough the liquid components, said draw ports corresponding in number to the liquid components; a discharge port for supplying the slurry to the chemical mechanical polishing machine; feed pumps arranged on feed lines for the liquid components, respectively, said feed lines extending from the individual draw ports to the discharge port,

such that the feed pumps can draw the corresponding liquid components in specific amounts to give the mixing ratio and can deliver the thus-drawn liquid components toward the discharge port, respectively; dampers and pressurization valves arranged in combinations on the respective feed lines on delivery sides of the feed pumps; flow-meters arranged on the respective feed lines on downstream sides of the corresponding combinations of the dampers and pressurization valves for measuring delivery rates from the corresponding feed pumps; and a programmable logic controller for controlling delivery rates of the individual feed pumps by using measurement values from the flow-meters.

[0010] In another aspect of the present invention, there is also provided a method for mixing and supplying, to plural chemical mechanical polishing machines, slurries at flow rates and with compositions as required by the chemical mechanical polishing machines. The method includes connecting slurry mixing and supplying apparatuses of the above-described construction to the chemical mechanical polishing machines , respectively, such that the liquid components, which comprise at least the dispersion of fine abrasive particles and the solution of the additive, can be parallelly supplied to the individual chemical mechanical polishing machines via the corresponding slurry mixing and supplying apparatuses. In another preferred embodiment, the present invention also provides a method as described above, which further includes

inputting from the individual chemical mechanical polishing machines to the programmable logic controller information on predetermined amounts of the individual liquid components required by the chemical mechanical polishing machines, respectively; monitoring for changes in the predetermined amounts; and performing control of delivery rates from the respective feed pumps by using differences of measurement values of the flow-meters from the predetermined amounts.

[0011]

[Modes for Carrying out the Invention]

The preferred embodiments being listed, the present invention will be described in detail. With a view to solving the above-described problems of the conventional art, the present inventors conducted an extensive investigation. As a result, it was found that in some instances, a conventional slurry mixing and supplying apparatus, in which a concentrated slurry and an additives solution are mixed together shortly before they reach a chemical mechanical polishing machine, may be unable to mix these liquid components at a high-accuracy mixing ratio and to supply the resulting slurry in a stable state. In view of this finding, it came to the present inventors' mind that the mixing ratio of liquid components, which includes at least a concentrated slurry and an additives solution, in a slurry would be successfully controlled with high accuracy if delivery rates of these liquid components from their corresponding feed pumps

can be stabilized by developing a means for reducing to minimum levels fluctuations in the delivery rates of the liquid components from the pumps upon feeding them. The present inventors have then proceeded with an investigation, leading to the completion of the present invention.

[0012] According to the investigation by the present inventors, plural liquid components to be fed to their corresponding feed pumps have their own optimal pressure conditions, respectively, and delivery rate characteristics of the feed pumps firstly depend on pressure fluctuations of the individual liquid components under feeding. These pressure fluctuations include those attributable to pulsations produced when pumps or the like are used to feed the individual liquid components and those attributable to effects from use of the liquid components at other chemical mechanical polishing machine(s). Interested in a finding that minimization of these pressure fluctuations can become useful means for minimizing fluctuations in the delivery rates of the liquid components from the corresponding feed pumps, the present inventors proceeded with developments. As a result, it has been found that use of such means makes it possible to feed a slurry to each chemical mechanical polishing machine at a high-accuracy mixing ratio of its liquid components, in a good state free of any substantial deterioration and in an appropriate and simple manner, because at optional flow rates suited for polishing work desired at the

chemical mechanical polishing machine, the liquid components are fed from the corresponding feed pumps while being maintained at accurate delivery rates.

[0013] Firstly, one of such means is to minimize pulsations associated with feeding of each liquid component by its corresponding feed pump. This approach will be described based on FIG. 1., which shows an illustrative slurry mixing and supplying apparatus according to one example of the present invention. The slurry mixing and supplying apparatus K is of the two liquid components mixing, and is used to mix two liquid components. The drawing shows a drum 1 filled with a concentrated slurry (hereinafter called "the liquid component A") containing fine abrasive particles such as silica, alumina or ceria dispersed in water in which a surfactant or the like is contained, and a drum 2 filled with an additives solution (hereinafter called "the liquid component B") which is to be mixed with the liquid component A and contains additives such as a surfactant, an oxidizing agent and the like. Designated at numeral 4 are pumps for recirculating the liquid components A, B, respectively. As the pumps 4, conventional pumps such as diaphragm pumps can be used. In combination with the pumps 4, unillustrated dampers may be arranged to dampen pulsations.

[0014] In FIG. 1, the liquid component A fed from the drum 1 and the liquid component B fed from the drum 2 are mixed together such that these liquid components are supplied at desired

specific flow rates to the chemical mechanical polishing machine 17. In the embodiment depicted in FIG. 1, the liquid component A and the liquid component B are both recirculated by the pumps 4. According to an investigation by the present inventors, it has been ascertained that pressure fluctuations, which are produced by delivery pressure and pulsations of each pump 4 itself, give an adverse effect on the accuracy of a delivery rate from the corresponding feed pump 5 and as a result, make it difficult to maintain an accurate delivery rate from the feed pump.

[0015] To cope with this problem, it may be contemplated to additionally arrange a correction system for these pressure fluctuations and to control delivery rates of the individual feed pumps 5. It has been found that good control is feasible by such a method. However, each feed pump 5 used generally has its own delivery rate characteristics (individual difference). It is, therefore, required to prepare as many correcting operation expressions as the feed pumps to be used. Upon setting up the apparatus or replacing the feed pumps 5, operation expressions have to be prepared again. Irksome work may hence be needed in some instances. According to a still further investigation by the present inventors, the arrangement of such a correction system was found to involve a practical problem in that as conditions for permitting control, limitations are imposed on the maximum pressures of the individual liquid components to be introduced into the mixing apparatus.

Accordingly, there is still a room for improvements in the above-described correction system.

[0016] The present inventors, therefore, have proceeded with a still further investigation. As a result, it has been found that a slurry can be supplied to a chemical mechanical polishing machine at a high-accuracy mixing ratio of its liquid components, in a good state free of any substantial deterioration and in an appropriate and simpler manner when flow-meters 8 are arranged on delivery-side feed lines of the individual feed pumps 5 to measure delivery rates from the individual feed pumps 5 and more preferably, when a programmable logic controller (hereinafter abbreviated as "PLC") 16 capable of monitoring for changes in desired delivery rates preset and inputted in connection with the individual feed pumps 5 and performing output control to allow the feed pumps to sufficiently follow up the changes in the preset delivery rates and also PID control by use of deviations of delivery rates (current values) obtained by the flow-meters 8 from their corresponding preset delivery rates (preset values) is additionally arranged to permit control of delivery rates from the individual feed pumps 5, because the above-described constitution can feed the liquid components accurately at desired flow rates suited for a desired polishing operation. This constitution will hereinafter be described with reference to FIG. 1.

[0017] Using, as targets, desired feeding flow rates set

beforehand at the mixing apparatus K or desired flow rate signals transmitted from the chemical mechanical polishing machine 17 (hereinafter abbreviated as "polishing machine 17") to the PLC 16, PLC 16 firstly transmits necessary flow rate signals to pump controllers 14 for the feed pumps 5. Each pump controller 14 processes the flow rate signal to convert it into a pump drive voltage so that the feed pump 5 is driven at a desired delivery rate. The flow-meter 8 arranged on the delivery-side feed line of each feed pump 5 measures an actual delivery rate of the liquid component from the feed pump 5.

[0018] Using a measurement value obtained by each flow-meter 8, the delivery rate of the feed pump 5 is controlled. As a premise for this control, the slurry mixing and supplying apparatus K according to the present invention makes a flow of each liquid component delivered from its corresponding feed pump 5 stable without fluctuations by a method to be described next. Described specifically, each liquid component is delivered from its corresponding feed pump 5 and is supplied to the polishing machine 17. If pulsations of the feed pumps 5 propagate to their corresponding liquid components, an adverse effect is given on the stable supply of the slurry. To reduce such an adverse effect, the present invention makes combined use of a damper 6 and a pressurization valve 7 on the delivery-side feed line of each feed pump 5. This constitution can significantly dampen pulsations of the feed pumps 5 so that the flows of the liquid

components delivered from the respective feed pumps 5 and supplied toward the polishing machine 17 can be maintained in stable states.

[0019] Described specifically, the arrangement of each damper 6 can dampen pulsations of the corresponding liquid caused by the associated feed pump 5. As a result, the liquid components delivered from their corresponding feed pumps 5 can be fed and mixed as stable flows. Further, the structure of each pressurization valve 7 employed in combination with its associated damper 6 is very close to the damper 6 and hence, the pressurization valve 7 is expected to have an effect to further dampen pulsations of the liquid component caused by the associated feed pump 5. As a result, the pulsations of the feed pumps 5 are significantly reduced, and therefore, the flows of liquid components delivered from the individual feed pumps 5 and supplied toward the polishing machine 17 are maintained stable to permit supplying a slurry at a high-accuracy mixing ratio of its liquid components.

[0020] In the present invention, a flow of each liquid component delivered from its corresponding feed pump 5 is maintained in a stable state by the adoption of the above-described means. Further, the delivery rates of the individual liquid components from its feed pumps 5 are continuously measured by the corresponding flow-meters 8 and more preferably, any changes in the preset values inputted as

liquid amounts desired for the individual feed pumps 5 are also monitored. By using these delivery rates and changes, control is performed such that the individual liquid components are stably supplied at accurate delivery rates to the polishing machine. A description will hereinafter be made about this control.

[0021] As illustrated in FIG. 1, delivery rates of the individual liquid components from the feed pumps 5, said delivery rates being continuously measured by the flow-meters 8, are inputted to PLC 16 via their flow-meter detectors 15. Firstly, PLC 16 is designed to permit continuous monitoring for deviations of readings (measurement values) of the individual flow-meters 8 from the desired feed flow rates of the corresponding liquid components set in advance at the slurry mixing and supplying apparatus K or from the feed flow rates obtained based on the desired flow rate signals (hereinafter called "preset flow rates") transmitted from the polishing machine 17 to PLC 16. The pump controllers 14 are feedback controlled using these deviations, respectively, such that the delivery rates from the feed pumps 5 are PID controlled to make them closer to the preset flow rates as targets. When these preset flow rates remain constant, it is sufficient to perform only this PID control. Where the desired preset flow rates are changed as occasion demands, however, it is difficult to perform control to fully follow up the changes if only the PID control

is relied upon. In some instances, it may therefore take substantial time until the delivery rates are stabilized at the corresponding preset flow rates as the targets. This is believed to be attributable to the existence of cases in each of which depending on the feed pumps, their response speeds are too slow to sufficiently follow up the speed of the PID control. In the present invention, it is hence preferred to perform control by making combined use of output control of the feed pumps and the PID control as described above. As flow-meters 8 usable for such control, those of the propagation time difference type making use of ultrasonic waves are preferred. Illustrative of such flow-meters is "USF200S" (tradename) manufactured by Tokyo Flow Meter Co., Ltd.

[0022] In the slurry mixing and supplying apparatus K according to the present invention, the individual liquid components are drawn in desired amounts by the feed pumps 5 and are delivered and fed toward a polisher 17, as described above. During this time, pulsations caused by each feed pump 5 are lessened by its associated damper 6 and pressurization valve 7 such that the state of delivery of the liquid component from the feed pump 5 is stably maintained. Concurrently with this, the delivery rate control system composed of the flow-meters 8 and PLC 16 is used in combination to suppress any adverse effect on the accuracy of delivery rates of the feed pumps 5, said adverse effect occurring by pressure fluctuations caused especially by

delivery pressures and pulsations of the recirculation pumps 4 themselves when the recirculation pumps 4 are used, so that control is performed to feed the individual liquid components accurately at the flow rates preset as targets, respectively. As a consequence, the slurry mixing and supplying apparatus according to the present invention, which makes use of the above-mentioned combination, can stably supply a slurry in a state free of any substantial deterioration to the polishing machine 17 while maintaining the mixing ratio of its liquid components with high accuracy. According to this embodiment, the above-described excellent effects can be achieved by the simple constitution that without arrangement of any complex correction system or control system, the flow-meters 8 are arranged on the outlet sides of the feed pumps 5 and the programmable logic controller is arranged to control the delivery rates of the feed pumps by using measurements values from the flow-meters.

[0023] In the example depicted in FIG. 1, the liquid component A and the liquid component B are both recirculated by their pumps 4. However, the present invention is not limited to such a design, and these liquid components may be force fed without using pumps in some instances. According to an investigation by the present inventors, especially when the recirculation pumps 4 were used, pressure fluctuations caused by delivery pressures and pulsations of the recirculation pumps

4 themselves gave an adverse effect on the accuracy of delivery rates from the feed pumps 5. A tendency was, therefore, observed to the effect that delivery rates were not maintained accurately and the mixing ratio in the slurry was not successfully maintained with high accuracy. Especially in a system making use of the slurry recirculation pumps 4, it is effective to perform the above-described control of delivery rates by the flow-meters 8 and PLC 16. Even when the liquid components are force fed to the feed pumps 5 without using the pumps, the arrangement of the above-described control system can of course achieve maintenance of accurate delivery rates from the supply pumps 5.

[0024] In the slurry mixing and supplying apparatus K of the present invention, it is also preferred to arrange an isolator 11 between at least one of the draw ports and its corresponding feed pump 5 as illustrated in FIG. 1. Adoption of this constitution is preferred especially for a non-settling slurry or an additives solution which contains no abrasive. A description will next be made about this embodiment. As mentioned above, an adverse effect may be produced on the accuracy of delivery rates from the feed pumps 5 when the recirculation pumps 4 or the like are used. Expecting that the above-described drawback would be successfully lessened further if the system in which recirculation is performed by the pumps 4 (hereinafter called "the recirculation system") and the system in which the

polishing and supplying of a slurry are conducted (the mixing and supplying apparatus K; hereinafter called "the mixing system") can be isolated from each other, the present inventors has proceed with a development of a device capable of achieving such an objective. As a result, use of an isolator having the structure shown in FIG. 2 has been found to be effective. Fig.2 shows illustratively an isolator 11 preferred to the present invention, however, based on FIG. 2, the structure of the isolator 11 will be described.

[0025] Fig.2 is a view of the isolator 11. The isolator 11 is in the form of a double-walled cylinder constructed of an outer cylinder 11A and an inner cylinder 11B arranged inside the outer cylinder 11A. The outer cylinder 11A is provided at two locations with liquid-level-sensors 13 for controlling liquid levels within the outer cylinder 11A. Designated at numeral 13H is a high level sensor, while indicated at numeral 13L is a low level sensor. In communication with the atmosphere, a vent 11C is also arranged at a location higher than the high level sensor 13H. Through a bottom part of the outer cylinder 11A, a feed line 11D is arranged in communication with the corresponding feed pump. A top wall of the outer cylinder 11A is arranged in an air-tight fashion, and the inner cylinder 11B is secured to the top wall in such a way that the former extends through the latter. An open end portion of the inner cylinder 11B, said lower end portion being arranged inside the outer

cylinder 11A, is located on a lower side than the low level sensor 13L.

[0026] When the isolator 11 of the above-described construction is arranged between the draw port and the feed pump 5 as illustrated in FIG. 1, the isolator 11 functions as will be described below and can isolate the recirculation system and the mixing system from each other. As a result, it is possible to suppress adverse effects on the accuracy of a delivery rate of the feed pump 5, said adverse effects occurring by pressure fluctuations produced by delivery pressure and pulsations of the pump 4 itself employed in the recirculation system. It is, therefore, possible to further reduce effects of the recirculation system on the mixing system. A further description will be made with reference to FIG. 2. The liquid component to be fed from the recirculation system, said recirculation system being provided with the recirculation pump 4, to the feed pump 5 is firstly introduced from the inner cylinder 11B into the outer cylinder 11A. As already mentioned in the above, the outer cylinder 11A is in communication with the atmosphere via the vent 11C so that in the isolator 11, the pressure of the liquid component B to be fed to the feed pump 5 is released into the atmosphere. As a consequence, the feed pump 5 draws the liquid component B which is stored in the isolator 11 and is in a non-pressurized state, and then delivers the same. Accordingly, the delivery rate of the feed pump 5 is controlled

without being affected by pressure fluctuations on the primary side (especially, on the side of the recirculation system).

[0027] When plural apparatuses K are arranged in parallel with each other in communication with the recirculation lines of the individual liquid components to supply the individual liquid components to plural polishing machines 17 as illustrated in FIG. 3, concurrent operation of plural ones of the apparatuses K without any isolation between the recirculation system and the mixing system as in the conventional art leads to fluctuations in the pressures of the liquid components under recirculation on the primary side or the liquid components under force feeding. These pressure fluctuations affect the pressures of the liquid components to the remaining mixing and supplying apparatus(es) K in operation. As mentioned above, however, the recirculation system and the mixing system, can be isolated from each other when the individual liquid components are designed to be drawn into the respective feed pumps 5 via isolators 11. This design can, therefore, cope with the above-mentioned problem.

[0028] No particular limitation is imposed on the material of the isolator 11 of the above-described construction insofar as it is excellent in chemical resistance and does not contaminate or otherwise deteriorate the individual liquid components. PFA (perfluoroalkoxyfluoroplastics), a fluorinated resin, or the like can be used, for example. As the liquid level sensors 13 of the isolator 11, on the other hand, use of capacitance

sensors is preferred. Capacitance sensors manufactured by Efector co., ltd. can be mentioned as such ones. It is, however, to be noted that the detection type of the sensors is not limited to the capacitance type and can be the photoelectric type or the like.

[0029] As a preferred embodiment of the above-described present invention, the slurry mixing and supplying apparatus can be additionally provided with a cleaning and flushing system which makes it possible to clean and flush the feed line of the concentrated slurry with deionized water. This modification can solve the clogging problem of the piping in the mixing and supplying apparatus due to settling and/or agglomeration of the slurry particles during feeding standby, and can maintain high accuracy with respect to the mixing ratio of the liquid components in the slurry even in an initial stage after the feeding is resumed subsequent to a temporary halt. Although the above-described cleaning and flushing system may be operated manually with deionized water, it can be constructed as an automated cleaning and flushing system. Such an automated cleaning and flushing system further facilitates maintenance work.

[0030] In the slurry mixing and supplying apparatus according to the present invention, the desired flow rates required for the polishing machine 17 can be inputted either directly to PLC 16 arranged in an main body of the slurry mixing and supplying apparatus K or by external transmission, which

makes use of a network, from the polishing machine 17 to which the slurry is supplied. Adoption of the inputting method, which relies upon external transmission, makes it possible to perform remote control such that the supplying state of the slurry can be adequately controlled while observing the state of chemical mechanical polishing by the polishing machine 17. As a consequence, it becomes possible to make improvements in operability and also to achieve more perfect planarity on a work, for example, a substrate under polishing.

[0031] In the above description, the mixing and supplying apparatus of the two liquid components mixing types was used to mix and supply two liquid components, that is, the liquid component A as a concentrated slurry and the liquid component B as an additives solution. However, the present invention is not limited to such a mixing and supplying apparatus, but can mix and supply liquid components as many as needed. For example, a mixing and supplying apparatus of the three liquid components mixing types can be constructed to mix and supply three liquid components by adding a system to feed deionized water in addition to the liquid component A and the liquid component B. This mixing and supplying apparatus of the three liquid components mixing type can dilute and mix the liquid component A and the liquid component B with deionized water into appropriate forms, and moreover, can facilitate operation upon cleaning and flushing with deionized water the piping for the liquid component A as

the concentrated slurry. As already mentioned in the above, the cleaning and flushing operation with deionized water can effectively solve the clogging problem of the piping in the mixing and supplying apparatus due to settling and/or agglomeration of the slurry particles during standby of slurry feeding. Incidentally, to modify the mixing and supplying apparatus of the two liquid components mixing shown in FIG. 1, it is only necessary to additionally provide a valve 9, with an inlet for cleaning and flushing, deionized water W so that the inside of the piping for the liquid component A can be cleaned and flushed with the deionized water.

[0032] A description will hereinafter be made of specific flows of the individual liquid components in the slurry mixing and supplying apparatus K according to the present invention. As illustrated in FIG. 1, the concentrated slurry as the liquid component A is firstly drawn by the recirculation pump 4 from the drum 1, delivered from the pump 4 and is returned back to the drum 1, so that the concentrated slurry is recirculated at a specific flow rate. Of the liquid components employed for the formation of the slurry, the concentrated slurry particularly involves the potential problem that the fine abrasive particles contained therein may settle. It is, therefore, preferred to feed it from the state of a recirculating flow to the feed pump 5 as illustrated by way of example in FIG. 1.

[0033] In the embodiment depicted in FIG. 1, a preset flow

rate signal from PLC 16 is converted into a drive voltage at the pump controller 14. Upon transmission of the drive voltage to the feed pump 5, the feed pump 5 is driven such that the liquid component A, which is recirculating at a predetermined flow rate, is fed to the feed pump 5 via the valve 9 and is then delivered at a preset, desired delivery rate from the feed pump 5. As illustrated in FIG. 1, adverse effects of pressure fluctuations in the recirculating flow of the liquid component A on the delivery rate of the liquid component A from the feed pump 5 during the above-described feeding are reduced as will be described below. Firstly, a delivery rate from the feed pump 5 is monitored by the flow-meter 8, and the monitoring is continuously performed for any deviations of readings (measurement values) of the flow-meter 8 from the desired, preset flow rate which has been inputted in PLC 16 to perform PID control. More preferably, concurrent monitoring is also performed for any changes in the preset delivery rates of the individual feed pumps 5 to perform output control such that the poor responsibility of any feed pump(s) 5, which cannot follow up the PID control, can be complemented. Information controlled by these means are fed to the pump controllers 14 to perform control such that the outputs of drive voltages to the feed pumps 5 are precisely corrected to ensure the delivery of the liquid components at the accurate delivery rates from the feed pumps 5.

[0034] The liquid component A delivered stably at the

specific flow rate from the feed pump 5 as described above is fed to the polisher 17 via the damper 6 and pressurization valve 7 arranged on the delivery-side feed line. Pulsations of the feed pump 5 are, therefore, dampened by these damper and pressurization valve so that adverse effects on the delivered flow, said adverse effects being caused by the pulsations, are reduced. The flows of the individual liquid components delivered from the corresponding feed pump 5 are hence maintained stable. As a consequence, a slurry with its liquid components mixed at a highly accurate ratio can be stably supplied to the polishing machine 17.

[0035] In the embodiment illustrated in FIG. 1, the liquid component B is also drawn by the pump 4 from the drum 2, delivered from the recirculation pump 4 and returned back to the drum 2 and hence, is recirculated at a specific flow rate, in a similar manner as the above-described recirculation of the liquid component A. Different from the concentrated slurry as the liquid component A, however, the additives solution as the liquid component B may be free of a potential problem such as settling depending on the kinds of the additives. It is, therefore, not absolutely necessary to recirculate the liquid component B by the pump 4. The liquid component B may thus be fed to the feed pump 5 by a force feed system without using any pump. Adverse effects of pressure fluctuations in the flow of the liquid component B by the recirculation or the force feed system on

the delivery rate from the feed pump 5 can be eliminated in a similar manner as in the above-described case of the liquid component A, i.e., by arranging the flow-meter 8, PLC 16 and the pump controller 14 and controlling the delivery rate from the feed pump 5. Where the additives solution as the liquid component B does not have settling property, it is preferred to arrange the isolator 11 between the draw port from the recirculation system of the liquid component B and the feed pump 5 as shown in FIG. 1. This construction can more stably maintain the flow of the liquid component delivered from the feed pump 5.

[0036] In the manner described above, the liquid components A and liquid component B are delivered from the corresponding feed pumps 5 at delivery rates accurately maintained with differences from the corresponding preset flow rates being reduced, and are also delivered in the form of flows maintained stable without being affected by pulsations of the feed pumps 5. These liquid component A and liquid component B are mixed together through a valve 10 and the mixer 12 which is arranged on the necessary response, and are supplied as a desired slurry to the polishing machine 17. The mixer 12 may be arranged as needed, although its arrangement is preferred to effectively conduct the mixing of plural liquid components. As a mixer usable for the above-mentioned purpose, a mixer manufactured by Noritake Company Limited or a like mixer can be mentioned.

[0037] The individual liquid components consisting of the liquid component A and the liquid component B are supplied to the polishing machine 17 as illustrated in FIG. 1 and also as described in the above. The individual liquid components, which have reached the valve 10, are at accurate flow rates reduced in difference from the corresponding preset flow rates, and moreover, are all in stable states free from effects of pulsations of the corresponding feed pumps 5. In the slurry formed as a mixture of these liquid components, the desired mixing ratio of the liquid components has, therefore, been achieved accurately.

[0038] As feed pumps for use in the present invention, to use constant flow rate pumps 5 are preferred. As constant flow rate pumps, tubephragm pumps, bellows pumps or diaphragm pumps are generally used. It is preferred to use tubephragm pumps in the present invention. A tubephragm pump has merits that it is free from slurry flocculation and its own pulsations are smaller than those of other pumps. In a tubephragm pump, a liquid is alternately drawn in a specific amount into tubephragms, for example, two tubephragms and is alternately delivered from the tubephragms. The liquid is, therefore, delivered stably at a particular flow rate. To reduce effects of pulsations of each feed pump 5 on its corresponding liquid component delivered from the feed pump 5, the present invention dampens the pulsations of the feed pump 5 by causing the liquid component to pass through

the associated damper 6 and pressurization valve 7 subsequent to its delivery from the feed pump 5 as already mentioned in the above.

[0039] As dampers 6 for use in the present invention, any dampers can be used insofar as they can dampen pulsations of the feed pumps 5 and can reduce adverse effects on the delivered liquid components. It is possible to use, for example, those of such a construction that the interior of each damper has the structure of a tubephragm, a fluid is caused to flow through the tubephragm, air of a predetermined pressure is introduced from the outside to compress the tubephragm inwards, and as a result, pressure fluctuations applied to the fluid upon its delivery from the feed pump 5 are dampened to reduce pulsations and to maintain a desired flow rate constantly.

[0040] As pressurization valves 7 for use in the present invention, it is possible to use, for example, those of such an orifice construction that the interior of each pressurization valve has the structure of a tubephragm, a fluid is caused to flow through the tubephragm, air of a predetermined pressure is introduced from the outside to compress the tubephragm inwards, and a restriction can be effected on the pressure of the fluid on the primary side of a tubephragm pump. Use of such a tubephragm structure is desired, because a damper effect can be expected and pulsations of the feed pump 5 can be more dampened than arrangement of the damper 6 alone.

[0041] In addition to the above-described damper effect, the use of the pressurization valve 7 can also bring about further advantageous effects especially as will be described below. Even when the recirculation system and the mixing system are isolated from each other by causing the interior of the above-described isolator to communicate with the atmosphere, certain small pressure fluctuations from the recirculation system, which have not been fully released into the atmosphere, are considered to give effects on the feed pump 5. In general, when a primary-side fluid which is to be drawn by a pump has a pressure, a situation called "fluid leak" occurs. As a consequence, there is a potential problem that this "fluid leak" may be added to a delivery rate to result in an error. This "fluid leak" can however, be prevented if a restriction is effected on (in other words, a back pressure is applied to) the fluid pressure on the primary side of the feed pump 5 by arranging the pressurization valve 7.

[0042] The present inventors next conducted an investigation about procedures for the feedback control of flow rates by PLC 16. As a result, it has been found that, as will be mentioned below, correction of a delivery rate from each feed pump by a combination of output control (a difference between a preset flow rate and a measurement value of the corresponding flow-meter) and PID control is particularly preferred. A description will hereinafter be made about the investigated

control procedures (A) to (C).

[0043] (A) Procedure shown in FIG. 4(a), in which each delivery rate from each feed pump is corrected by output control alone.

FIG. 4 shows a control flow for correcting delivery rate by output control alone. According to this procedure, control is performed as will be described below.

(1) Amounts of the individual liquid components, which are required by the polishing machine 17, are inputted as preset flow rate values in PLC 16.

(2) PLC 16 outputs the preset flow rate values as flow rate signals to the pump controllers 14.

(3) The pump controllers 14 output drive voltages to the feed pumps 5.

(4) Flow rates of the liquid components actually delivered by the feed pumps 5 are measured by the flow-meters 8.

(5) Measurement values by the flow-meters 8 are inputted as flow-meter measurement values to PLC 16 via the flow-meter detectors 15.

(6) PLC 16 determines differences between the inputted preset flow rate values and the inputted flow-meter measurement values, and based on the differences, corrects the outputs of drive voltages to the feed pumps 5 via the corresponding pump controllers 14 such that flow-meter measurement values become closer to their corresponding preset flow rate values.

(7) The procedure is returned to the step (1).

[0044] As a result of performance of the above-described output control, it has been found that as illustrated in FIG. 4(b), the difference between a preset flow rate value and a flow-meter measurement value may be not fully corrected in some instances by the control which directly corrects only the output of a drive voltage to the feed pump 5.

[0045] (B) Procedure shown in FIG. 5(a), in which each delivery rate from feed pump is corrected by PID control alone.

FIG. 5 shows a control flow for correcting delivery rate by PID control alone. According to this procedure, control is performed as will be described below.

(1) Amounts of the individual liquid components, which are required by the polishing machine 17, are inputted as preset flow rate values in PLC 16.

(2) PLC 16 outputs the preset flow rate values as flow rate signals to the pump controllers 14.

(3) The pump controllers 14 output drive voltages to the feed pumps 5.

(4) Flow rates of the liquid components actually delivered by the feed pumps 5 are measured by the flow-meters 8.

(5) Measurement values by the flow-meters 8 are inputted as flow-meter measurement values to PLC 16 via the flow-meter detectors 15.

(6) PLC 16 determines deviations of the inputted flow-meter

measurement values from the inputted preset flow rate values, and using the deviations, corrects the outputs of drive voltages to the feed pumps 5 via the corresponding pump controllers 14 such that flow-meter measurement values become closer to their corresponding preset flow rate values.

(7) The procedure is returned to the step (1).

[0046] As a result of performance of the above-described output control, it has been found that as illustrated in FIG. 5(b), overshoots and undershoots become larger relative to changes in the flow rate value preset as a target when the above-described correction of the output of a drive voltage to the feed pump 5 is performed by the output correction procedure making use of PID control alone. In other words, it has been found that errors in flow rate are very large and substantial time is required until the flow rate becomes stable. One of causes of such large overshoots and undershoots is presumably attributable to a failure of the pump response speed in following up the speed of the PID control due to the slow response characteristic of the feed pump when the flow rate varies considerably.

[0047] (C) Procedure shown in FIG. 6(a), in which each delivery rate from each feed pump is corrected by the combination of output control and PID control.

FIG. 6 shows a control flow for correcting each delivery rate by the combination of output control and PID control.

According to this procedure, control is performed as will be described below.

(1) PLC 16 continuously monitors for changes in the preset flow rate value as a target and also for deviations of measured flow rate values obtained by the flow-meter 8 from the preset flow rate value.

(2) When any change in the preset flow rate value as the target exceeds 5% per unit time, an input to PLC 16 is performed using a circuit A.

(3) PLC 16 outputs a flow rate signal to the pump controller 14.

(4) The pump controller 14 outputs a drive voltage to the feed pump 5.

(5) A flow rate of the liquid component actually delivered by the feed pump 5 is measured by the flow-meter 8.

(6) A measurement value by the flow-meter 8 is inputted as a flow-meter measurement value to PLC 16 via the flow-meter detector 15.

(7) When the deviation of a flow-meter measurement value from the preset flow rate value exceeds 5%, the circuit A is used. When this deviation returns to within 5%, switching to a circuit B is performed.

(8) When switched to the circuit B, PLC 16 determines a deviation of a flow-meter measurement value from the preset flow rate value inputted as the target and, while performing PID

control, corrects an output such that the flow-meter measurement value becomes closer to the preset flow rate value.

(9) The procedure is returned to the step (1).

[0048] As a result of performance of the above-described output control, it has been confirmed that as illustrated in FIG. 6(b), a delivery rate with a preset flow rate value realized very stably can be achieved. Described specifically, the flow-meter measurement value can be brought into closer conformity with the preset flow rate value when use is made of the control method by the combination of output control and PID control that, when a change takes is made to a flow rate value preset as a target, only the output of a drive voltage to the feed pump is directly changed as a first step to bring it closer to within 5% of the preset flow rate value and after confirmation of its achievement, the control is switched to PID control and a precise correction is performed in the switched state. As a result, the individual liquid components are supplied at accurate delivery rates to the polishing machine; the slurry mixing and supplying apparatus can maintain with high accuracy the mixing ratio of the slurry.

[0049]

[Advantageous Effect of Present Invention]

The slurry mixing and supplying apparatus and method according to the present invention can supply a slurry at an optional flow rate suited for desired working or machining to

a chemical mechanical polishing machine, with its liquid components mixed together at a high-accuracy mixing ratio, in a good state free of any substantial deterioration, and in an appropriate and simpler manner. The apparatus and method according to the present invention can maintain the mixing ratio of a slurry with high accuracy even in an initial stage after a supply of the slurry is resumed subsequent to a temporary halt.

[Brief Description of the Drawings]

[FIG. 1]

A schematic view of a apparatus of the present invention.

[FIG. 2]

A schematic cross-sectional view of an isolator usable in the apparatus of the present invention.

[FIG. 3]

A schematic construction diagram illustrating an application of the apparatus of FIG. 1 to plural chemical mechanical polishing machines.

[FIG. 4]

A block diagram of a control system usable in the apparatus of the present invention.

[FIG. 5]

A block diagram of a control system usable in the apparatus of the present invention.

[FIG. 6]

A block diagram of a control system usable in the apparatus of the present invention.

[Explanation of Symbols]

1,2 : A drum

4: Pumps for recirculation

5: Feed Pumps

6: Dampers

7: Pressurization valves

8: Flow-meters

9, 10: Valves

11: An isolator

12: A mixer

13: Liquid-level sensors (13H: higher level; 13L: lower level)

14: A pump controller

15: Flow-meter detectors

16: PLC

17: A chemical mechanical polishing apparatus

K: A slurry-mixing and -supplying apparatus

[Name of Document] Abstract

[Abstract]

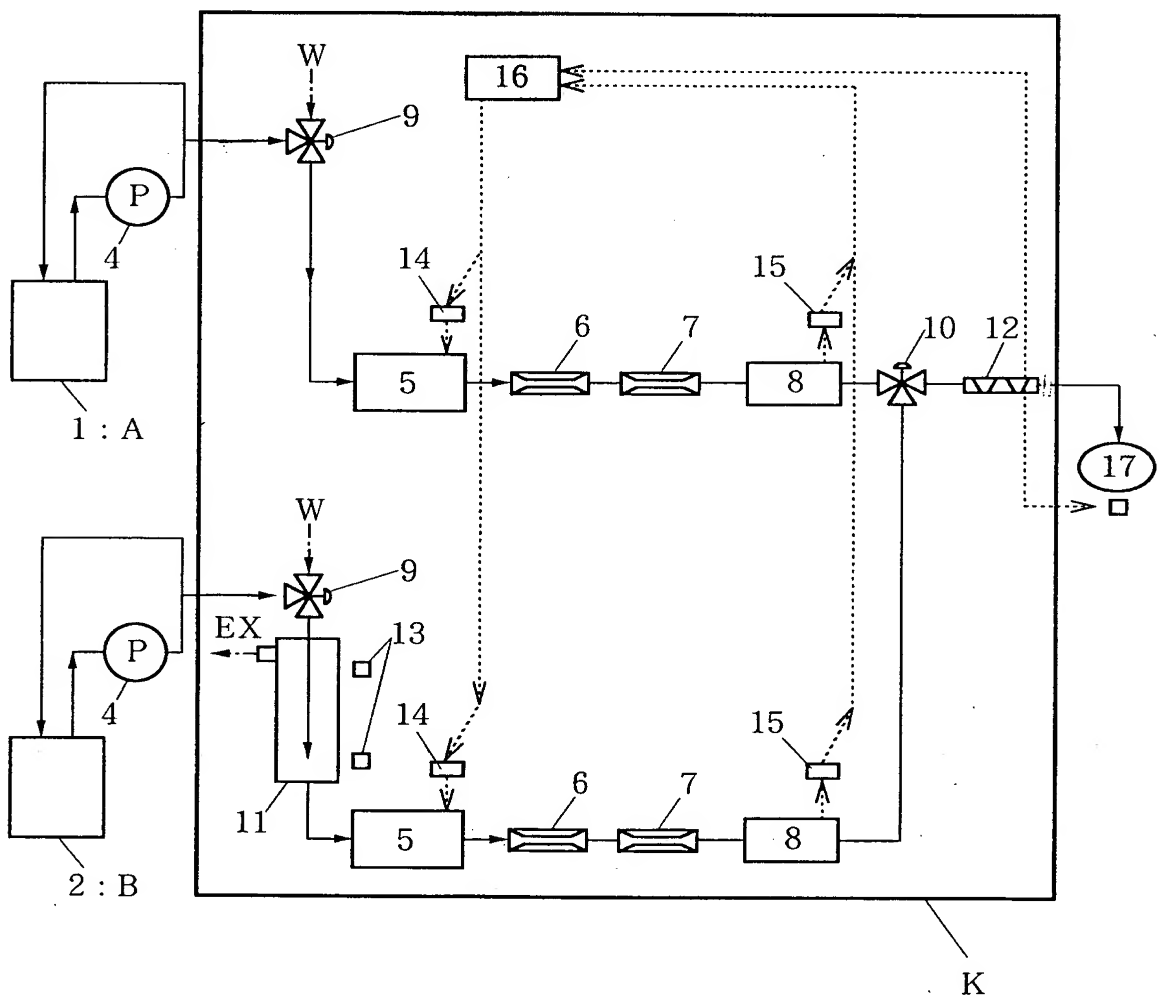
[Problems to be Solved] To provide a slurry-mixing and -supplying apparatus, which apparatus is capable of mixing slurry in accurate mixing-ratios of liquid components and supplying the mixed slurry in good condition to a polishing apparatus; and a method for mixing and supplying slurry.

[Means for the Solution] An apparatus for mixing and supplying a slurry to a chemical mechanical polishing machine, which apparatus comprises: draw ports for separately drawing therethrough the liquid components; a discharge port for supplying the slurry to the machine; feed pumps arranged on feed lines for the liquid components, respectively, said feed lines extending from the individual draw ports to the discharge port, such that the feed pumps can draw the corresponding liquid components in specific amounts to give the mixing ratio and can deliver the thus-drawn liquid components toward the discharge port, respectively; dampers and pressurization valves arranged in combinations on the respective feed lines on delivery sides of the feed pumps; flow-meters arranged on downstream sides of the corresponding combinations of the dampers and pressurization valves; and a programmable logic controller for controlling delivery rates of the individual feed pumps by using measurement values from the flow-meters.

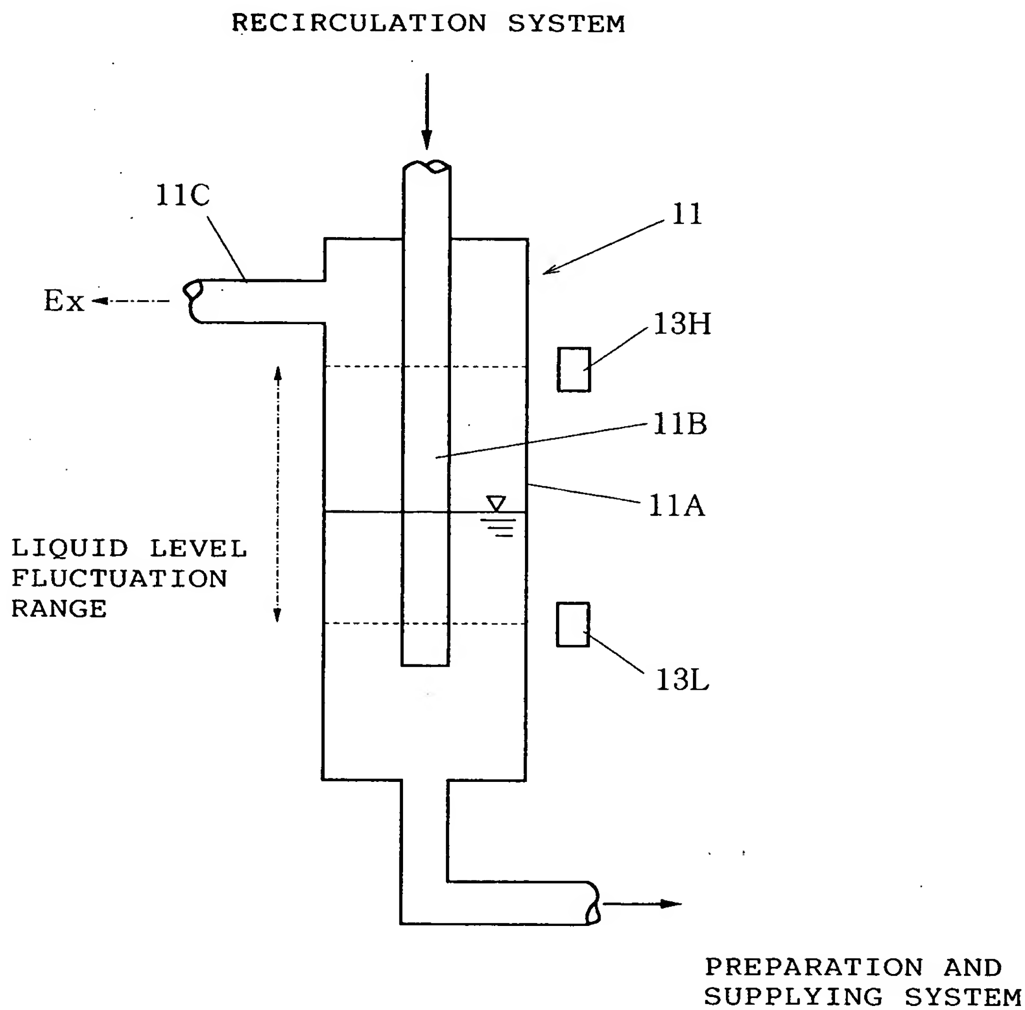
[Selected Drawings] Figure 1

[Name of Documents] Drawings

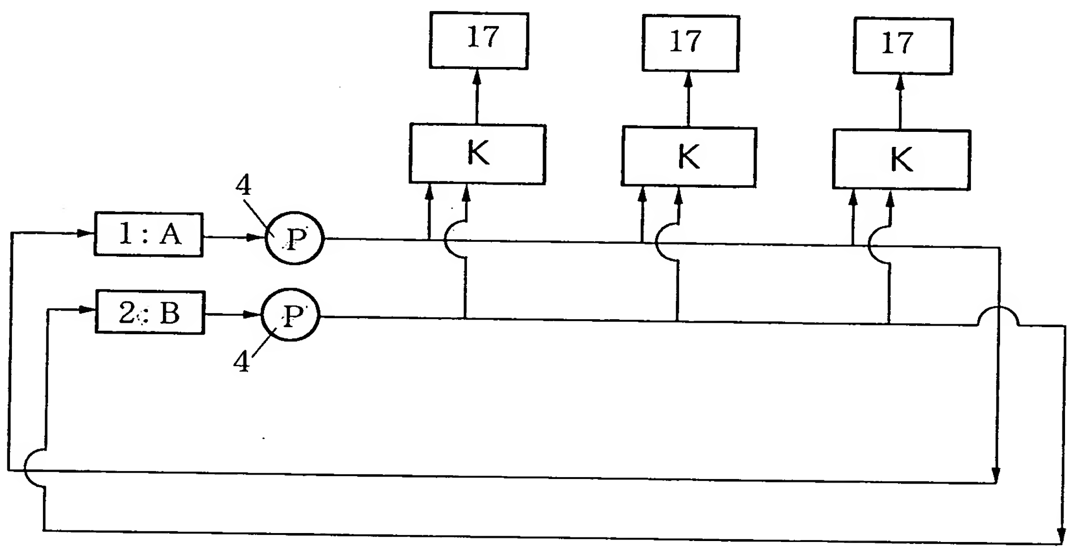
[Fig. 1]



[Fig. 2]

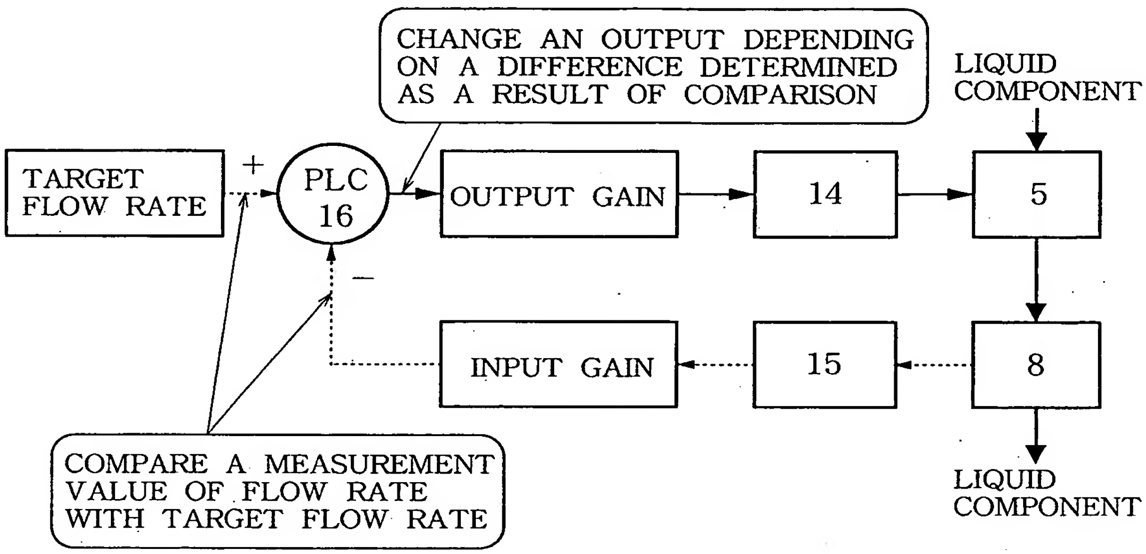

RECIRCULATION SYSTEM
11C
11
Ex
13H
11B
11A
LIQUID LEVEL
FLUCTUATION
RANGE
13L
PREPARATION AND
SUPPLYING SYSTEM

[Fig. 3]

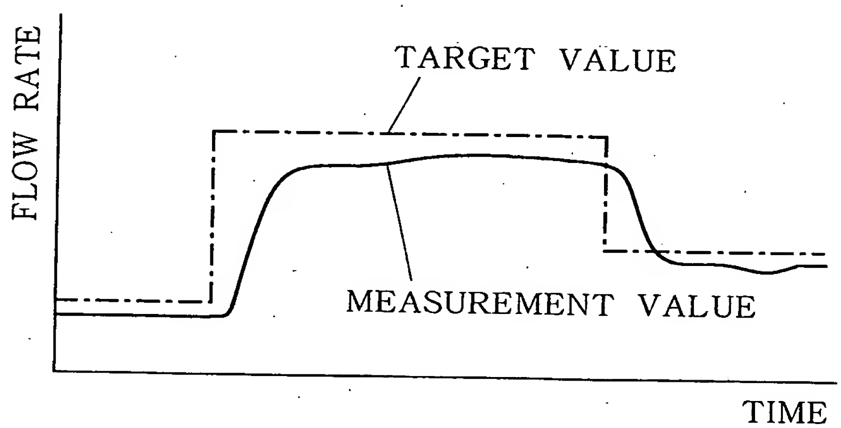


[Fig. 4]

(A)

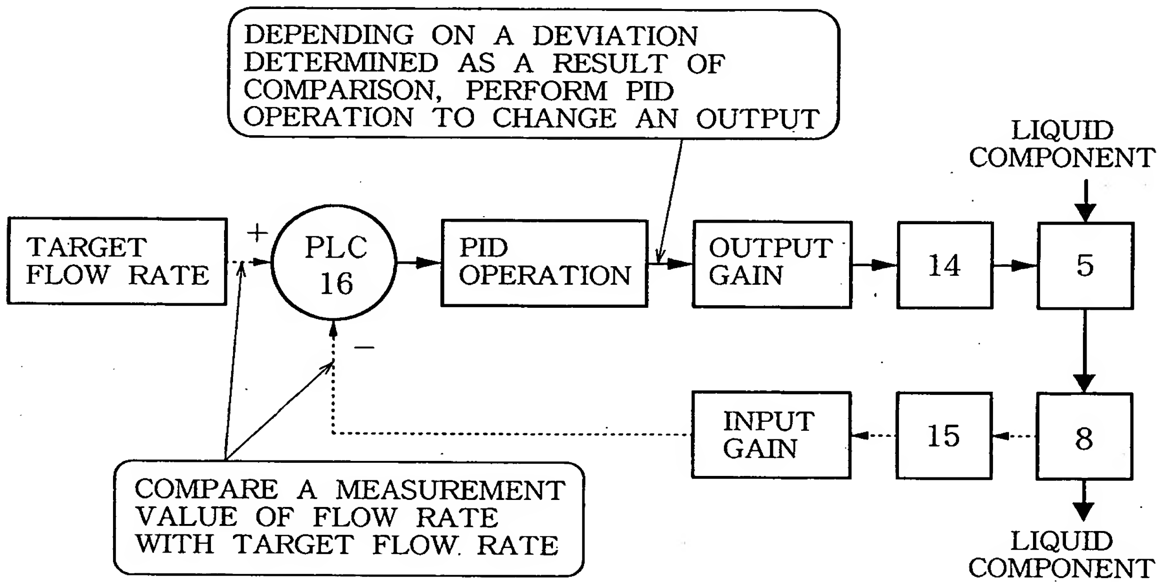

CHANGE AN OUTPUT DEPENDING ON A DIFFERENCE DETERMINED AS A RESULT OF COMPARISON
LIQUID COMPONENT
TARGET FLOW RATE
+
PLC 16
OUTPUT GAIN
14
5
−
INPUT GAIN
15
8
COMPARE A MEASUREMENT VALUE OF FLOW RATE WITH TARGET FLOW RATE
LIQUID COMPONENT

(B)

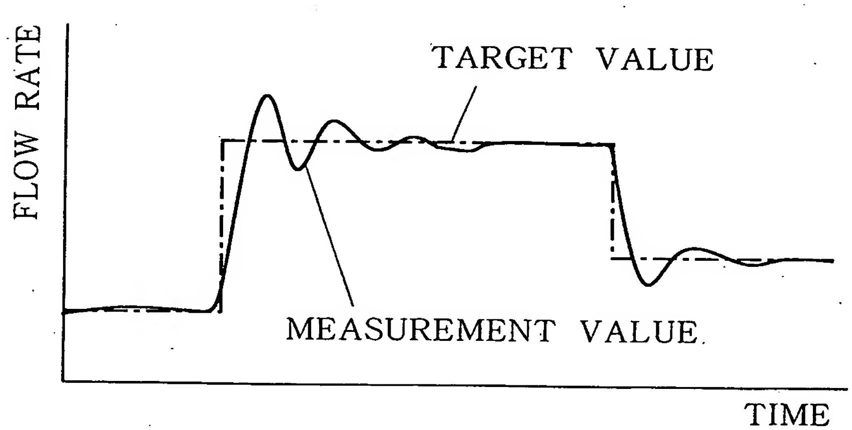

FLOW RATE
TARGET VALUE
MEASUREMENT VALUE
TIME

[Fig. 5]

(A)

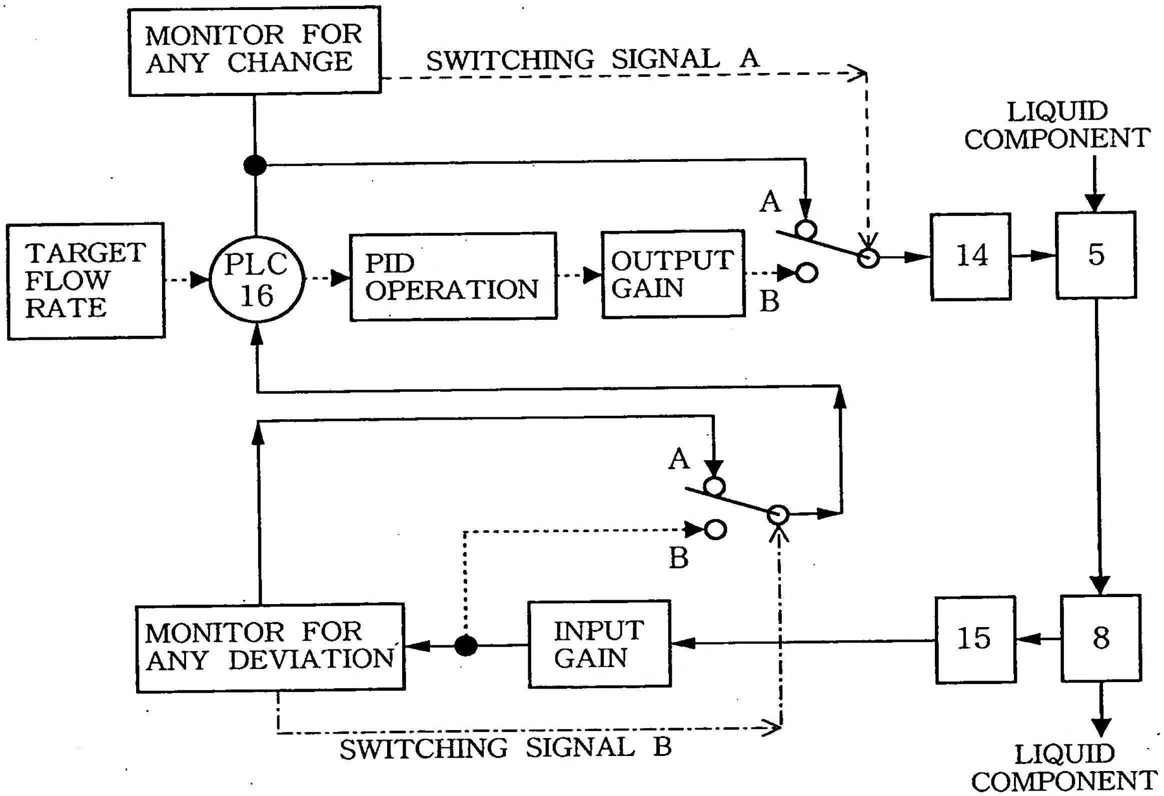

DEPENDING ON A DEVIATION DETERMINED AS A RESULT OF COMPARISON, PERFORM PID OPERATION TO CHANGE AN OUTPUT
LIQUID COMPONENT
TARGET FLOW RATE
+
PLC 16
−
PID OPERATION
OUTPUT GAIN
14
5
INPUT GAIN
15
8
COMPARE A MEASUREMENT VALUE OF FLOW RATE WITH TARGET FLOW RATE
LIQUID COMPONENT

(B)

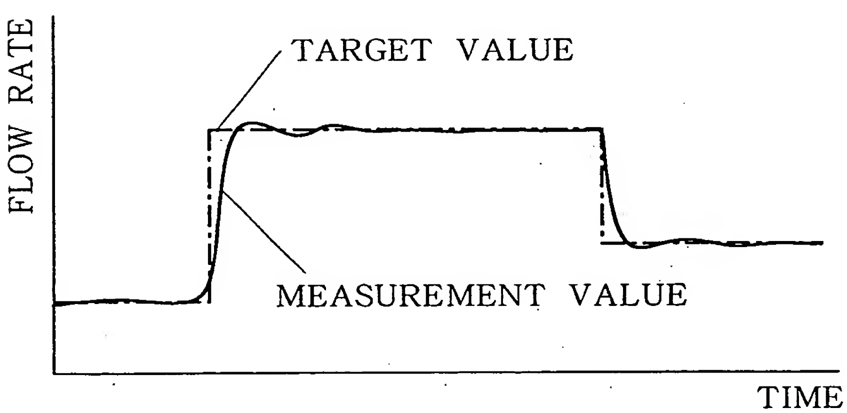

FLOW RATE
TARGET VALUE
MEASUREMENT VALUE
TIME

[Fig. 6]

(A)


MONITOR FOR ANY CHANGE
SWITCHING SIGNAL A
LIQUID COMPONENT
A
TARGET FLOW RATE
PLC 16
PID OPERATION
OUTPUT GAIN
B
14
5
A
B
MONITOR FOR ANY DEVIATION
INPUT GAIN
15
8
SWITCHING SIGNAL B
LIQUID COMPONENT

(B)


FLOW RATE
TARGET VALUE
MEASUREMENT VALUE
TIME